MEASUREMENT OF SYSTEMIC RISK – A CRITICAL REVIEW OF SELECTED MODELS

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ABSTRACT-Financial instability can lead to financial crises due to its spillover effects to other parts of the economy. Having an accurate measure of systemic risk gives academicians and policy makers the ability to make proper policies in order to predict systemic risks in advance and prevent a financial crisis as soon as warning signals indicate a possible economic disaster. For the purpose of this study the works of past researchers have been analyzed to study the effectiveness of various measures of systemic risk based on market data. Several experts have undergone systematic studies related to this area and have quantified the aggregate level of systemic risk in the economy. The results show that each measure predicts the systemic risk significantly. However each measure suffers its own set of limitations. SRISK, MES and CCA are more accurate in comparison to CoVaR, Granger Causality for identifying systemically important financial institutions.

KEYWORDS : **systemic risk, SRISK, MES, Financial Stress Index**

INTRODUCTION

The great recession of 2007-2009 has brought the interest of market participants, academicians as well regulators to understand various dimensions of systemic risks. It brought the realization that just the regulation of individual Indian financial institutions is not enough but also their interconnectedness plays a major role at the times of crisis.

Whenever a system is undercapitalized, it will no longer be able to supply credit for ordinary everyday business .Thus; a capital shortfall is dangerous for not only a firm and its bondholders, but also dangerous for the whole economy. In response, many countries now produce a 'Financial Stability Report', each of which is grounded in certain datasets and mechanisms for measurement.

A report by moneycontrol.com stated that the PNB scam of Rs 11,400 Crore raises questions on systemic risks and audit processes in the country. The Rs 11,400 crore banking fraud has raised glaring concerns on the irregularities in Indian auditing and banking systems.

RBI identified SBI and ICICI banks as domestic systemically important banks (DSIBs) during 2015 and 2016 based on its own framework issued in July 2014. Hence identifying systemically important financial institutions has become a major concern in the current scenario.

This paper is an attempt to explore the available measures of systemic risk. To understand their application and find out the best suited measure.

Systemic risk

Systemic risk is a kind of risk that leads to disruption of the flow of financial services caused by an impairment of different parts of the financial system and has the potential to have serious negative consequences on the real economy. Therefore, measuring the financial systemic importance of financial institutions is crucial in identifying the potentially destabilizing constituents of the global financial system. Several ways have been proposed in the recent literature, from – without being exhaustive: cascade network representations, early warning signals with or without private information, degrees of connectedness – to quantitative measures of extreme under-performances and their impacts.

Measures of systemic risks

There are two major approaches to measurement of systemic risk, first approach relies on proprietary data, such as cross-holdings, interbank lending, derivatives positions, or common exposures to exogenous sources of risk and a second approach relies on public market data, such as stock or option prices, or CDS spreads etc.

Critical Review of Measures of Systemic Risk

(Brownlees & Engle, 2016) define the "Systemic RISK" (SRISK) as a measure of systemic risk proposed by Acharya et al. (2012) based on market data. It is the expected capital shortfall of a financial entity conditional on a prolonged market decline. SRISK is a function of the size of the firm, its degree of leverage, and its expected equity loss conditional on the market decline, which we call Long Run Marginal Expected Shortfall (LRMES).

Firms with the highest SRISK are the largest contributors to the undercapitalization of the financial system in times of distress. It can be understood as the total amount of capital that the government would have to provide to bail out the financial system in case of a crisis.

(Grinderslev & Kristiansen, 2016) studied the model of SRISK for firm i at time t as

$SRISK_{i,t} = E_t[CS_{i,t+h}|Crisis_{t:t+h}]$

where

CS = Capital Shortfall

t + h is the future point in time at which the crisis occurs.

To calculate SRISK, one needs to specify three things: 1. How to measure the capital shortfall. 2. How a crisis is defined. 3. How to relate the crisis and the capital shortfall, such that the capital shortfall conditional on a systemic event can be estimated.

Following Brownless and Engle (2015), the capital shortfall for firm i at time t is defined by

$CS_{i,t} = k \cdot A_{i,t} - MV_{i,t}$ (1)

$= k \cdot (D_{i,t} + MV_{i,t}) - MV_{i,t},$ (2)

Where,

$MV_{i,t}$ is the market value of equity,

$D_{i,t}$ is the book value of debt and

$A_{i,t} = D_{i,t} + MV_{i,t}$ is quasi assets" for firm i at time t.

k is the prudential capital fraction, i.e. the minimal share of the quasi assets firm i is meant to fund using equity

The crisis in SRISK is defined to be a general stock market crash over the next h days of at least C percent

$Crisis_{t:t+h} = \{R_{M,t:t+h} \leq C\}$ (3)

with $R_{M,t:t+h}$ being the cumulative market return over the next h days.

Using the earlier definition of SRISK along with the definitions of capital shortfall and a crisis, the following expression for SRISK can be written

$SRISK_{i,t} = E_t[CS_{i,t+h}|Crisis_{t:t+h}]$ (4)

$= E_t[k \cdot (D_{i,t+h} + MV_{i,t+h}) - MV_{i,t+h}|R_{M,t:t+h} \leq C]$ (5)

(Tavolaro & Visnovsky, 2014) highlight the following limitations of SRISK :-

- SRISK does not refers to groups that are partially listed or unlisted, a quite frequent situation in Europe.
- The ranking procedure mixs different accounting standards between institutions without considering their differences and implications.
- Reflecting the perception of market participants, market data do not necessarily reflect the fundamentals of financial
- The assumption that that the market capitalization coincides perfectly with equity's value is not true. It is common to observe large differences between them
- The SRISK framework does not consider that a financial institution may go into insolvency, where the bankruptcy of an institution implies losses to all its creditors or to estimate the cost of a resolution.

CoVaR conditional value at risk

(Fullenkamp, 2013) used a technique for capturing a financial institution's contribution to systemic risk based on market data and the value-at-risk (VaR) methodology. The "Co" in CoVaR stands for Conditional.

Systemic Risk is measured by the VaR of the financial system while CoVaR measures what happens to the system's VaR when one particular institution is under financial stress, as measured by its own individual VaR

The q% VaR is the "minimum large loss" that occurs only q% of the time, or the loss that is not exceeded (1- q%) of the time .VaR(q), as the number that satisfies

$Pr(X \leq VaR_q) = q$

For measuring systemic risk, X should be a function of the market value of the institution's assets

– Market Value of Assets (MVA)

– Change in MVA

Let $CoVaR_q^{j|i}$ denote the VaR of a set of institutions) j, conditional on some event C (X^i) occurring to institution i

$Pr[X^j \leq CoVaR_q^{j|C(X)i})|C(X^i)] = q$

CoVaR simply tells us the boundary on a large loss for some institution(s), given that a particular institution is stressed to a certain degree.

ΔCoVaR

One way to measure the contribution to systemic risk is to show what happens when an institution changes from "normal" to "stressed" . "Normal" means that its asset values are at their median, while "stressed" means that its asset values are at the q-percent VaR level .

Change in the boundary of large-loss region for institution j when institution i goes from a "normal" to a "stressed" realization of X.

When j is a financial system, $\Delta CoVaR_q^{j|i}$ gives an estimate of institution i's contribution to systemic risk—how much the system's large loss increases because of firm i's stress

$CoVaR^{i|j}{}_q = CoVaR_q^{j|Xi=VaRiq} - CoVaRq^{j|X(i)= median(i)}$

(Raupach & Löffler, 2015) found that the ΔCoVaR responds to idiosyncratic risk in an ambiguous way. When applied in regulation, the use of ΔCoVaR could create incentives for banks to increase idiosyncratic risk in order to lower their estimated systemic risk contribution. The ΔCoVaR has a tendency to assign a low systemic risk to infectious banks, others tend to do the opposite.

Granger Causality

(Aggarwal, Arora, Behl, Grover, Khanna, & Thomas, 2013) ,realized that to investigate the dynamic propagation of systemic risk, it is important to measure not only the degree of interconnectedness between financial institutions, but also the directionality of such relationships. To that end, they propose using Granger causality, a statistical notion of causality based on the relative forecast power of two time series

$$R^i_{t+1} = a^i R^i_t + b^{ij} R^j_t + \varepsilon^i_{t+1}$$

$$R^j_{t+1} = a^j R^j_t + b^{ji} R^i_t + \varepsilon^j_{t+1}$$

R^i_t and R^j_t represent the time series of the stock market ,whereas i and j indicate the two institutions of a given pair, t stands for time and Ɛ indicates the error term. and a^i, a^j, b^{ij} b^{ji} are the coefficients of the model.If b^{ij} is different from zero then R^j Granger causes R^i and if b^{ji} is different from zero then Granger causes R^j.

Billio et al. (2012) computed different types of interconnections and identified the number of out-connections as the best measure of systemic risk. GC measure computed as the proportion of significant out-connections for each firm is given as:

$$100 \times \frac{\text{number of out connections}}{\text{total number of possible connections}}$$

(PANKOKE, 2014) concluded that companies which Granger-cause stock market returns of many other companies contribute most to systemic risk. It was also found that companies whose stock market returns are heavily influenced by the returns of other companies can be considered vulnerable. The results about whether the Granger-causality relationships can successfully indicate the companies which contribute to systemic risk are mixed.

Marginal Expected Shortfall, MES

The MES is a systemic risk measure introduced by Acharya et al. (2010). The general idea is to measure the expected magnitude of a crisis. Following Acharya et al. (2010), the MES of a financial firm as its short-run expected equity loss conditional on the market taking a loss greater than its Value-at-Risk at α%. Let $r_{i,t}$ denote the daily (log) stock return of the firm and r_{mt} the daily index return of the larger market the firm belongs to. Then the MES can be written as :

$MES_{i,t}=E_t(r_{i,t+1} \mid r_{m,t+1}<q_{\alpha t}(r_{t+1}) = C)$ (1) or

$MES_{i,t} = E_t (r_{i,t+1} \mid r_{m,t+1} < C)$ (2)

The smaller the MES, the higher the systemic risk contribution.

(Bernard, Brechmann, & Czado, 2013) identified that the MES of a company considers the stock market returns, but only considers the returns of a company when the entire market is in a slump. However, previous studies have not tested if the "tail returns" considered by MES do have more explanatory power ex ante than stock market returns.

Therefore, the measure focuses on the expected contribution of an institution to the aggregated capital loss during a crisis but not on the probability of a systemic crisis to occur.

CONTINGENT CLAIM ANALYSIS

(Acharaya, Pedersen, & Richardson, 2011) proposed contingent claim analysis as a structural approach of measuring systemic risk of a financial using the financial institution's assets.

This model integrates market-implied expected losses in a multivariate specification of joint default risk to quantify an individual institution's contribution to systemic solvency risk under normal and stressed conditions.

Lehar (2005) proposes a systemic risk measure based on the probability of default of a given proportion of organizations in a given financial system. The probability of default is linked to the relationship between the banks' asset value and their liabilities.

However the technique is complex and resource-intensive. There are complexities in applying the contingent claims analysis in practice due to the strong assumptions that need to be made about the liability structure of the financial institutions

FINANCIAL STRESS INDEX

(Duca & Peltonen, 2011) Constructed a Financial Stress Index (FSI) for different countries and evaluated at which levels it had negative implications for the real economy. The larger and broader the shock is, the higher the comovement among variables reflecting tensions. FSI is a country-specific composite index.

It consists of the following five components:

(1)The spread of the 3-month interbank rate over the 3-month Government bill rate

(2) negative quarterly equity returns

(3) the realised volatility of the main equity index

(4) the realised volatility of the nominal effective exchange rate and

(5) the realised volatility of the yield on the 3- month Government bill.

Each component j of the index for country i at quarter t is transformed into an integer that ranges from 0 to 3 according to the country-specific quartile of the distribution the observation at quarter t belongs to ($q_{j,i,t}$).

The Financial Stress Index is computed for country i at time t as a simple average of the transformed variables as follows:

$$FSI = \sum^{n}_{i=1} q_{j,I,t}(Ind_{j,i,t})/ n$$

Table 1: Comparison of selected Models of Systemic Risk

Model	Variable used	Interpretation	Limitations	Research application
SRISK Introduced in 2017	conditional expectation capital shortfall quasi assets" for firm book value of debt market value of equity cumulative market return	Total amount of capital that would be required to bail out the financial firm conditional on a financial crisis. Higher the value of SRISK riskier is the firm.	- not applicable to partially listed or unlisted companies - different accounting standards mixed to estimate ranking - Reflecting only the perception of market participants - temporarily bubbles, fads, etc, cannot be diagnosed	- Widely Used - Tested in Indian Context
VaR Introduced in 1993	Market value of assets	Loss that will not be exceeded at some specified confidence level	- Does not compare two dissimilar risks	- Widely Used - Tested in Indian Context
CoVaR Introduced in 2011	Market value of assets	Maximum large loss for some institution(s), given that a particular institution is stressed to a certain Degree	- Does not show the impact of organization on overall market	- Widely used - Widely tested in Indian context
Δ CoVaR Introduced in2011	market value of assets	The smaller the □*CoVaR*, the higher the systemic risk contribution	- Responds to idiosyncratic risk in an ambiguous way. - assigns a low systemic risk to infectious banks	- Widely used - Widely tested in Indian context
Granger Causality Introduced in 1969	the time series return of the stock market	If b^{ij} is different from zero then R^j Granger causes R^i and if b^{ji} is different from zero then Granger causes R^j. The more interconnections, the higher the systemic risk contribution	- Mixed predictability for different set of organizations.	- Widely used - Widely used for individual firms - Very few studies on financial system as a whole
MES Introduced in 2011	the daily (log) stock return of the firm daily index return of the larger market E_t=expected equity loss	The smaller the MES, the higher the systemic risk contribution.	- Does not focus on the contribution of an institution to the probability of a systemic crisis, but on its impact on the severity	- Widely Used in studies - Few studies comparing Public Sector and Private sector banks in India
FSI Introduced in 2006	Equity returns Interbank rates	Higher the value, greater the risk.	- Different for different countries	- Limited used - Country specific
CCA Introduced in 2010-2011	Equity prices	Probability of default using banks assets and liabilities	- Complex and resource intensive	- Limited used

CONCLUSION AND DISCUSSION

The critical review of available models shows that estimation of systemic risk has been done by several approaches by researchers. The commonality between the models is the data intensive method required for each model. While some models like CoVaR , Granger Causality are relatively easy to estimate but they have limitations in terms of prediction of systemic risk. More suitable models like Srisk ,MES and contingent claim analysis are complicated but more predictive. These models need to be tested in Indian context. Further, these models must be augmented to include balance sheet information about the companies.

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